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The Edinburgh Cognitive and Behavioural ALS Screen; relationship to age, education, IQ and the Addenbrooke's Cognitive Examination-III.

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Abstract

The Edinburgh Cognitive and Behavioural ALS Screen (ECAS) was developed to assess cognitive and behavioural changes common in Amyotrophic Lateral Sclerosis and other diseases affecting motor functions. It focuses on domains typically affected by the frontotemporal syndrome (executive and language functions, fluency and behaviour), but assesses also memory and visuospatial functions.

Objectives:

- A. To investigate the relationship between the ECAS and the Addenbrooke's Cognitive Examination (ACE-III).
- B. To investigate the effects of age, education, and IQ on the ECAS and create appropriate cut-off scores to determine abnormality.

Methods:

- A: 57 healthy participants (aged 35-80) were assessed with the ECAS, the Wechsler Abbreviated Scale of Intelligence (WASI-II), and the ACE-III.
- B: 80 healthy participants (aged 51-80) were divided into four groups according to age and education and were tested with the ECAS and the WASI-II.

Results:

The ECAS and the ACE-III have a good convergent validity with a significant correlation. Regression analysis revealed that IQ, followed by age, were the strongest predictors of the total ECAS score. IQ predicted 24% of the ECAS and 46% of the ACE-III variance. Education was not a significant predictor over and above IQ for both the ECAS and the ACE-III. Abnormality cut-off scores adjusted for age and education are presented.

Conclusions:

The ECAS shows good convergent validity with the ACE-III, but is less influenced by intelligence and presents less ceiling effects. The inclusion of an executive function assessment and behavioural interview in the ECAS makes it particularly useful for the assessment of frontal lobe disorders.

Key words: ECAS, education, age, IQ, frontotemporal dementia, screen, cognition, behaviour

Introduction

The Edinburgh Cognitive and Behavioural ALS Screen (ECAS) was developed to assess the cognitive and behavioural changes associated with ALS (1) since a significant percentage of these patients develop a fronto-temporal degenerative syndrome (2,3). The neuropsychological profile of ALS is somewhat heterogeneous and previous existent cognitive screening tests did not assess the full range of cognitive and behaviour change present in ALS, and most were not suitable for patients with physical disability. The ECAS has proven to be sensitive to detect the changes in executive functions, fluency, and language in patients with ALS; in addition, it was designed to differentiate these changes from those found in other pathologies, including Alzheimer's disease (1). It has also been validated against extensive neuropsychology showing high sensitivity and specificity (4,5) and against other screening tests including the Frontal Assessment Battery (FAB), Montreal Cognitive Assessment (MoCA) and Consortium to Establish a Registry for Alzheimer's Disease plus Scale (CERAD plus) (6,7).

The Addenbrooke's Cognitive Examination (ACE-III) is a widely used dementia screening test in the UK (8). It is proven to have very good diagnostic accuracy for patients with memory complaints (9); with greater accuracy than the Montreal Cognitive Assessment (MoCA), the Mini-Mental State Examination and the Memory Impairment Screen (10). We chose the ACE-III to compare against the ECAS over other screening tests, because it is one of the most commonly used cognitive tests in the UK and beyond to diagnose dementia. It has been validated in a number of patient groups (11,12,13). Furthermore, both the ACE-III and ECAS are multidomain and have similar assessment times (14, 15, 16). Although designed for the detection of different types of dementia, its sensitivity to detecting frontotemporal dementia and in particular the behavioural variant (bvFTD) is inconsistent (17,18,19). Hsieh et al. (20)

showed that patients with bvFTD displayed a cognitive profile consisting of deficits in verbal memory, attention, fluency and language using the ACE-III. However, apart from verbal fluency, the ACE-III does not include an assessment of executive functions, the most prominent cognitive deficit in this type of dementia. Furthermore, the sensitivity and specificity of the given cut-off scores are for a general diagnosis of dementia that comprises Alzheimer's Disease, bvFTD and Primary Progressive Aphasia. They propose that fronto-temporal dementia should be confirmed with specific functional and behavioural inventories such as the Cambridge Behavioural Inventory, the Neuropsychiatric Inventory or the Frontotemporal Dementia Rating Scale FRS (FTDFRS). Given the inclusion of tests of executive functions and an informant interview to detect abnormal behaviours, based on the most recent diagnostic criteria for bvFTD (21), the ECAS may be a more suitable test to assess this type of dementia.

The effect of demographic factors including age and education has been explored using local and/or translated versions in German, Italian, Chinese and Irish (6,7,5,22,23) but not in a British population. Age has been found to significantly correlate with total ECAS scores in most studies (6,7,5,22), with the exception of one (23). Although education was shown to correlate with ECAS scores across studies, the relation to measures of IQ has not been explored. Given the correlation between age and education found in the German, Italian and Irish studies, age and education adjusted local normative data have been produced.

This study had two primary aims:

- Objective 1: Investigate the relationship between the ECAS and Addenbrooke's Cognitive Examination (ACE-III).
- Objective 2: Investigate the effect of age, education, and IQ on the ECAS in a healthy population to create appropriate adjusted cut-off scores to detect abnormality.

Method

A. Relationship between the ECAS and the ACE-III

Participants

Healthy individuals (n=57) between the ages of 35 to 80 years old were recruited from the local population and the Psychology Volunteer Panel of the University of Edinburgh. Participants did not have any neurological illness in their medical history, or current psychiatric illness, or any learning disabilities. All were native English speakers.

A minimum of 55 participants was decided for this study, in order to predict a medium effect size ($f^2 = 0.15$) (24), with an alpha of 0.05 and a power of 0.80 in a linear regression of one predictor (25). A sample size of 55 is also adequate for predicting a large effect size ($p = 0.5$), with an alpha of 0.05 and a power of 0.80 in a correlation (minimum sample size would have been of 21). Both calculations were done using G*Power (26).

Materials

The Edinburgh Cognitive and Behavioural ALS Screen (ECAS). The ECAS is a short screening test (15-20 min) created to assess symptoms associated with cognitive and or behavioural impairment present in ALS. The ECAS is multidomain, providing subscores for language, fluency, executive, memory and visuospatial abilities. Language is evaluated by naming, comprehension and spelling. Fluency is measured by a free production of words beginning with the letter 's' and a restrained production of words beginning with the letter 't' but with only four letters. Executive functions are measured by a reverse digit span, alternation of letters and numbers, inhibitory sentence completion, and social cognition. Memory includes

measurements of immediate recall, delayed percentage retention and delayed recognition. Visuospatial abilities are measured with dot and cube counting, and number location. The ECAS also includes a behaviour interview based on diagnostic criteria for bvFTD that is undertaken with an informant/carer (1, see <http://ecas.psy.ed.ac.uk>).

Addenbrooke's Cognitive Examination (ACE-III). The ACE-III is a commonly used screening test for dementia. It assesses the abilities of attention, memory, fluency, language and visuospatial functions (27).

Wechsler Abbreviated Scale of Intelligence (WASI-II). The WASI-II is the brief version of the Wechsler Adult Intelligence Scale. We used the 15 minutes version with 2 subtests to obtain a measure of intelligence (Vocabulary and Matrix Reasoning) (28).

B. The Effect of Age and IQ on the ECAS

Participants

A total of 80 participants undertook this study. Thirty-three participants from the first study were included; and an additional 47 healthy individuals between the ages of 51 to 80, recruited from the local population and the Psychology Volunteer Panel of the University of Edinburgh. Participants did not have any neurological illness in their medical history, or current psychiatric illness, or learning disabilities. All were native English speakers. Social economical status was obtained based on the occupation of the participants. The classification was done according to the Standard Occupational Classification proposed by the Office for National Statistics (29).

Participants were divided into 4 groups according to their age and education. Age: 51-65 years old and 66-80 years old, these age ranges were chosen to parallel typically used division for early versus late onset dementia. Education: secondary school or a technical degree vs university degree, or postgraduate degree. A minimum of 19 participants per group was decided in order to predict a large effect size ($f = 0.40$) (24), this number of participants was obtained using an alpha of 0.05 and a power of 0.80 (25) for a one-way ANOVA using G*Power (26), we included in some of the groups 1 or 2 more participants in case we needed to exclude some outliers.

Ethical Approval

This study was approved by The Psychology Research Ethics Committee of the University of Edinburgh.

Statistical Analysis

The data were analysed using SPSS statistics version 22. Pearson's correlations were used to assess the relationship between variables. ANOVA and t Tests were undertaken on parametric data to assess the difference between groups. ANOVA stepwise linear regression was used to find the variables that predicted the final score of the ECAS. ANOVA linear regressions were done to find the effect of IQ on the ECAS and the ACE-III.

Results

A. Relationship between ECAS and ACE-III

The sample had 34 males and 23 females with a mean age of 56 years (± 13.29 , 35-80). The age of when they finished education was of 19.22 years (± 3.20 , 14-26), and their mean IQ was of 111.23 (± 16.73 , 75-156). Performance of participants on the ECAS and the ACE-III is presented in Table 1. The total scores of the ACE-III and the ECAS were significantly and moderately correlated ($r = .538$, $p < 0.001$). Memory ($r = .368$, $p = 0.005$), Fluency ($r = .503$, $p < 0.001$) and Language ($r = .411$, $p = 0.002$) correlated significantly between screens, however Visuospatial abilities ($r = .197$, $p < 0.141$) did not correlate between both tests.

As can be seen in Figure 1 the ACE-III suffered from more ceiling effects than the ECAS with some participants achieving full marks for the ACE-III, whereas none reached the maximum score for the ECAS. ANOVA linear regression models showed that 24% of the variance of the total score of the ECAS ($F(1,54)=17.292$, $p < .001$) was predicted by IQ ($\beta=.492$, $t=4.15$, $p < .001$), whereas 46% of the variance of the total score of the ACE-III ($F(1,54)=46.187$, $p < .001$) was predicted by IQ ($\beta=.679$, $t=6.79$, $p < .001$).

Overall, the scores of the domains of the ACE-III were more dependent on IQ than the domains in the ECAS. The percentage of the variance explained by IQ was higher in the ACE-III for the domains of Memory (29% vs 22%) and Visuospatial (7% vs 2%). Language was the same for both tests (30%). Fluency was more dependent on IQ for the ECAS (12% vs 21%). The percentage of the variance explained by IQ was 16% for Attention on the ACE-III and 9% for the Executive domain on the ECAS.

B. The effect of age, education and IQ.

Demographics of the full sample are presented in Table 2. There were no significant differences regarding IQ ($F(1,78)=.681, p=.412$) nor in socioeconomic status ($F(1,78)=1.084, p=.301$). Three outliers (more than 2 standard deviations from the mean) in the ECAS total score were removed from the data in the further analyses. The remaining sample presents scores from 97 to 134 on the total score of the ECAS.

An ANOVA stepwise linear regression model was undertaken including the variables of gender, age, education, and IQ. The most significant model predicted 32.5% of the variance of the ECAS Total Score ($F(3,73)=11.736, p<.001$). This model included the variables of IQ ($\beta=.557, t=5.54, p<.001$), age ($\beta=-2.82, t=-2.81, p=.006$) and gender ($\beta=.197, t=2.04, p=.045$). Education was not significant in the model since it could be sufficiently explained by IQ ($r = .514, p < 0.001$). Women scored slightly higher on the total score of the ECAS (119.16) in comparison to men (116.21).

Abnormality Cut-off scores

Education and age adjusted cut offs for abnormality are presented based on Education (those with and without a university degree) and age (below and above 65). Abnormality cut-offs were based on the 5 percentile (Table 3). Education was chosen over IQ to create the cut-off scores for the ease of use in association with the ECAS within the MND clinical services, since it is more easily available to than IQ.

Discussion

This study demonstrated that the ECAS has a good convergent validity with a commonly used dementia screening test, the ACE-III. A comparison of performance on the two assessments revealed that the ECAS has less ceiling effects overall in comparison with the ACE-III, since not one of the healthy participants scored full marks on the ECAS. Performance on the ECAS also seems to be less influenced by intelligence levels in comparison with the ACE-III, as IQ predicted 24% of the variance of the ECAS against 46% in the ACE-III. Visuospatial scores were more dependent on IQ in the ACE-III (7% as compared with the ECAS 2%) which is most likely related to the drawing component of the cube and the clock tasks. Fluency was more dependent on IQ in the ECAS (21%) as compared with the ACE-III (12%) which may be related to the inclusion of a constrained fluency in the ECAS and the more demanding lexical search for 4 letter words. Overall, IQ predicted more variance in the ACE-III over the ECAS which is most likely related to the different demands of the tests. The ACE-III includes the drawing figures such as a cube, the repetition of complex words and phrases and the inclusion of general knowledge questions. It is likely that some if not all of these components may be performed better in people with higher IQ.

All domains of the ECAS correlated with their counterparts in the ACE-III apart from visuospatial functions. The lack of correlation between the measurements of visuospatial abilities may be related to different methods used to assess these functions in the two tests. The ECAS was created for people with physical disability, and therefore does not include drawing, which is required for the ACE-III. For patients with motor dysfunction impairment on the visual task in the ACE-III could be due to motor problems (weakness, dyspraxia or rigidity, interfering with the quality of drawing), while the ECAS reflects visuospatial functions

independently of motor skills. A more in depth comparison of the ECAS and ACE-III in measuring the cognitive decline with patients of different dementias, in particular Alzheimer's Disease and Frontotemporal Dementia, is needed to evaluate the utility of these tests in diagnosing and assessing change of the different pathologies. The ECAS may also be applied as a useful cognitive screening tool in other neurological disorders characterised by motor as well as cognitive dysfunction, such as Progressive Supranuclear Palsy (30) or Corticobasal Degeneration (31)

The average IQ of some of our groups was higher than what you would expect in a normal population, which may be a limitation of the study. However, the literature indicates that when a sample comes from volunteers rather than randomly selected, the subjects tend to be healthier, have completed more years of education and have higher cognitive abilities (32, 33, 34, 35). We attempted to control for this during the recruitment process, by recruiting through churches, sport centres and outside schools; and successfully controlled for years of education. It is of note that most studies which validate dementia screening tests, do not measure IQ but rely on education level as a group descriptor, and it is therefore likely that the samples used in these studies would have a higher IQ than average, similar to our study, since it is a characteristic of the volunteer sample.

IQ, age and gender were significant predictors of the total score of the ECAS. The correlation of the ECAS with age has been found previously in the German-Swiss versions of the ECAS (6,22), the Italian version (7), and the Irish version (5). Education was not a significant predictor of the ECAS when IQ was included in the model because of their strong correlation. The influence of IQ on the ECAS has not been measured previously. Somewhat surprisingly in our sample, gender was also a significant predictor of performance on the ECAS, although

much weaker than age and IQ. Gender was not reported to significantly affect ECAS performance in two previous studies (7,23). In our study, women performed slightly better than men on ECAS Total Score. Within the ECAS domains, this effect was most pronounced in the Executive functions predicting 3% of the variance of the score but this difference did not reach significance.

Overall the cut-off scores for abnormality suggested from these findings were similar to those originally proposed (1), but nevertheless, may help to discern the impairment in cases where the score falls in the borderline range (4). In such situations, age and education can be taken into account; for example a score of 105 on the ECAS would not signify an impairment for someone in their 70's and without a university degree, whereas the same score would indicate a possible impairment for someone in their 50's with a university degree.

It is noted that our sample did not include people younger than 51 nor older than 80. People under 50 with a diagnosis of dementia represent 0.35% of the dementia population in Scotland (36), and it is advised in these cases that the same cut-off as 51-65 could be used. Future studies could look at creating separate cut-off scores for those over the age of 80, as they represent a larger percentage of the population with dementia (36).

Conclusion

The ECAS shows good convergent validity with the ACE-III, but is less influenced by intelligence and presents less ceiling effects in comparison to the ACE-III. Therefore, the ECAS is a suitable screening tool in particular in those: where cognitive assessment is complicated by the presence of motor symptoms; with executive dysfunction symptoms; and

those highly educated high-performers with mild cognitive impairment or early dementia. The inclusion of both assessments of executive functions and behaviour makes the ECAS an appropriate choice for the assessment of frontal lobes disorders.

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Declaration of interest

The authors have no known conflict of interest in relation to the publication of this paper.

References

1. Abrahams, S., Newton, J., Niven, E., Foley, J., and Bak, T, (2014). Screening for cognition and behaviour changes in ALS. *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*. 15 (1-2): 9-14
2. Goldstein, L.H. and Abrahams, S. (2013) Changes in cognition and behaviour in amyotrophic lateral sclerosis: nature of impairment and implications for assessment. *Lancet Neurol*, 12, 368-380
3. Strong, M., Abrahams, S., Goldstein, L., Woolley, S., McLaughlin, P., Snowden, J. et al. (2017) Amyotrophic lateral sclerosis – frontotemporal spectrum disorder (ALS-FTSD): Revised diagnostic criteria. *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*. 18, (3-4), 153-174
4. Niven, E., Newton, J., Foley, J., Colville, S., Swinger, R., Chandran, S. et al. (2015) Validation of the Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen (ECAS): A cognitive tool for motor disorders. *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*. 16 (3-4): 172-179
5. Pinto-Grau, M., Burke, T., Lonergan, K., McHugh, C., Mays, I., Madden, C. et al. (2017) Screening for cognitive dysfunction in ALS: validation of the Edinburgh Cognitive and Behavioural ALS Screen (ECAS) using age and education adjusted normative data. *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*. 18 (1-2) 99-106
6. Lulé, D., Burkhardt, C., Abdulla, S., Böhm, S., Kollwe, K., Uttner, I. et al. (2015) The Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen: A cross-sectional comparison of established screening tools in a German-Swiss population. *Amyotrophic Lateral Sclerosis and Frontotemporal Dementia*. 16 (1-2): 16-23

7. Poletti, B., Solca, F., Carelli, L., Madotto, F., Lafronza, A., Faini, A. et al. (2016) The validation of the Italian Edinburgh Cognitive and Behavioural ALS Screen (ECAS). *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*. 17, (7-8): 489-498
8. Jeyapaul, P. and Kerwick, S. (2008) Addenbrooke's Cognitive Examination as a better discriminator of cognitive impairment than the Mini-mental State Examination in patients with dementia. *International Psychogeriatrics*. 20, (3) 642-643
9. Jubb, M. and Evans, J. (2015) An Investigation of the Utility of the Addenbrooke's Cognitive Examination III in the Early Detection of Dementia in Memory Clinic Patients Aged over 75 years. *Dementia and Geriatric Cognitive Disorders*. 40, (3-4), 222-232
10. Matías-Guiu, J.A., Valles-Salgado, M., Rognoni, T., Hamre-Gil, F., Moreno-Ramos, T., and Matías-Guiu, J. (2017) Comparative Diagnostic Accuracy of the ACE-III, MIS, MMSE, MoCA, and RUDAS for Screening of Alzheimer Disease. *Dementia and Geriatric Cognitive Disorders*. 43, (5-6), 237-246
11. Lees, R.A., Hendry BA, K., Broomfield, N., Stott, D., Lerner, A.J. and Quinn, T. (2017) Cognitive assessment in stroke: feasibility and test properties using differing approaches to scoring of incomplete items. *International Journal of Geriatric Psychiatry*, 32 (10), 1072-1078
12. Davies, R., Dawson, K., Mioshi, E., Erzinçlioğlu, S., and Hodges, J.R. (2008) Differentiation of semantic dementia and Alzheimer's disease using the Addenbrooke's Cognitive Examination (ACE). *International Journal of Geriatric Psychiatry*, 23 (4), 370-375
13. McColgan, P., Evans, J.R., Breen, D.P., Mason, S.L., Barker, R.A., and Williams-Gray, C.H. (2012) Addenbrooke's Cognitive Examination-Revised for mild cognitive impairment in Parkinson's disease. *Movement Disorders*, 27(9), 1172-1176

14. Velayudhan, L., Ryu, S., Raczek, M., Philpot, M., Lindesay, J. et al. (2014) Review of brief cognitive tests for patients with suspected dementia. *International Psychogeriatrics*. 24 (8), 1247-1262
15. Newman, C.G.J., Bevins, A.D., Zajicek, J.P., Hodges, J.R., Vuillermoz, E. et al. (2018) Improving the quality of cognitive screening assessments: ACEmobile, and iPad-based version of the Addenbrooke's Cognitive Examination-III. *Alzheimers Dement (Amst)*. 10, 182-187
16. Morris, R.G., and Brookes, R.L. (2013) Neuropsychological Assessment of Older Adults. In L.H. Goldstein and J.E. McNeil (Eds.) *Clinical Neuropsychology: A Practical Guide to Assessment and Management for Clinicians*, Second Edition (pp. 347-373), Chichester, West Sussex: John Wiley & Sons
17. Yoshida, H., Terada, S., Honda, H., Ata, T., Takeda, N., Kishimoto, Y. et al. (2011) Validation of Addenbrooke's cognitive examination for detecting early dementia in a Japanese population. *Psychiatry Research*. 185, 211-214
18. Bier, J.C., Ventura, M., Donckels, V., Van Eyll, E., Claes, T., Slama, H. et al. (2004) Is the Addenbrooke's Cognitive Examination effective to detect frontotemporal dementia? *Journal of Neurology*, 251, 428-431
19. Elamin, M., Holloway, G., Bak, T.H. and Pal, S. (2015) The Utility of the Addenbrooke's Cognitive Examination Version Three in Early-Onset Dementia. *Dementia and Geriatric Cognitive Disorders*. 41, (1-2), 9-15
20. Hsieh, S., Schubert, S., Hoon, C., Mioshi, E. and Hodges, J.R. (2013) Validation of the Addenbrooke's Cognitive Examination III in Frontotemporal Dementia and Alzheimer's Disease. *Dementia and Geriatric Cognitive Disorders*. 36, 242-250

21. Rascovsky, K., Hodges, J.R., Knopman, D., Mendez, M.F., Kramer, J.H., Neuhaus, J. et al. (2011) Sensitivity of revised diagnostic criteria for the behavioural variant of frontotemporal dementia. *Brain*. 134 (pt9): 2456-77
22. Loose, M., Burkhardt, C., Aho-Özhan, H., Keller, J., Abdulla, S., Böhm, S. et al. (2016) Age and education-matched cut-off scores for the revised German/Swiss-German version of ECAS. *Amyotrophic Lateral Sclerosis and Frontotemporal Dementia*. 17, (5-6): 374-376
23. Ye, S., Ji, Y., Li, C., He, J., Liu, X. and Fan, D. (2016) The Edinburgh Cognitive and Behavioural ALS Screen in a Chinese Amyotrophic Lateral Sclerosis Population. *Plos One*. 11(5): e0155496
24. Cohen, J. (1988) *Statistical Power Analysis for the Behavioural Sciences*. Hillside, N.J.; Hove: Lawrence Erlbaum, pp. 287, 478
25. Field, A. (2009) *Discovering Statistics using SPSS*, 3rd edn, London, UK:SAGE, pp. 69, 115
26. Faul, F., Erdfelder, E., Lang, A.G., and Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behaviour, and biomedical sciences. *Behavior Research Methods*, 39, 175-191
27. Noone, P. (2015) The Addenbroke's Cognitive Examination-III. *Occupational Medicine*. 65, (5): 418-420
28. Wechsler, D. (2011) *Wechsler Abbreviated Scale of Intelligence – Second Edition*. San Antonio, Texas: Pearson.
29. Office for National Statistics (2010) SOC2010 volume 3: the National Statistics Socio-economic classification (NS-SEC rebased on SOC2010) <http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/o>

ns/guide-method/classifications/current-standard-classifications/soc2010/soc2010-volume-3-ns-sec--rebased-on-soc2010--user-manual/index.html

30. Colosimo, C., Bak, T.H., Bologna, M., and Berardelli, A. (2014) Fifty years of progressive supranuclear palsy. *Journal of Neurology, Neurosurgery & Psychiatry*, 85 (8), 938-944
31. Bak, T.H., Hodges, J.R. (2008) Corticobasal Degeneration: clinical aspects in Duyckaerts, C. & Litvan, I., (eds) *Handbook of Clinical Neurology: Dementias*, 509-521
32. Ganguli, M., Lytle, M. E., Reynolds, M. D., and Dodge, H.H. (1998) Random Versus Volunteer Selection for a Community-Based Study, *Journal of Gerontology: MEDICAL SCIENCES*, 53A, 1, M39-M46
33. Henrich, J., Heine, S. J., and Norenzayan, A. (2010) The weirdest people in the world? *Behavioral and Brain Sciences*, 33, 61-135
34. Arnett, B., and Rikli, R. (1981) Effects of Method of Subject Selection (Volunteer vs Random) and Treatment Variable on Motor Performance, *Research Quarterly for Exercise and Sport*, 52:4, 433-440
35. Wrights, A.P., Fain, C.W., Miller, M.E., Rejeski, W.J., Williamson, J.D., and Marsh, A.P. (2015) Assessing physical and cognitive function of older adults in continuing care retirement communities: Who are we recruiting? *Contemporary Clinical Trials*. 40, 159-165
36. Prince, M., Knapp, M., Guerchet, M., McCrone, M., Prina, P. et al. (2014) *Dementia UK: Update* Second Edition report produced by King's College London and the London School of Economic for the Alzheimer's Society, p. 61

Tables and Figures

Table 1: Performance on the ECAS and ACE-III:

N=57	(max)	Mean (SD)	Median (range)
ECAS total	136	115.87 (± 11.30)	118 (88-134)
ECAS language	28	26.71 (± 1.81)	27 (20-28)
ECAS fluency	24	19.40 (± 3.46)	20 (10-24)
ECAS executive	48	39.71 (± 4.69)	40 (22-47)
ECAS memory	24	19.22 (± 3.57)	20 (7-24)
ECAS visuospatial	12	11.59 (± 0.90)	12 (7-12)
ACE-III total	100	93.07 (± 4.81)	94 (80-100)
ACE-III attention	18	17.01 (± 1.10)	17 (13-18)
ACE-III memory	26	23.10 (± 2.93)	24 (15-26)
ACE-III fluency	14	12.59 (± 1.29)	13 (9-14)
ACE-III language	26	25.33 (± 0.87)	26 (23-26)
ACE-III visuospatial	16	15.01 (± 1.14)	15 (11-16)

Standard Deviation (SD), Edinburgh Cognitive and Behavioural ALS Screen (ECAS),

Addenbrooke's Cognitive Examination (ACE-III). Maximum score (max)

Table 2: Demographics of The effect of age, education and IQ.

Age group	Education group	Participants	Age	Age at finishing education	IQ
51-65	1	20 total	58.3	17.35	108.30
		(10 m)	(± 4.64)	(± 2.08)	(± 14.56)
			52-65	15-24	75-139
	2	21 total	59.23	22.52	128.38
		(11 m)	(± 3.72)	(± 1.36)	(± 11.34)
			51-65	21-26	103-156
66-80	1	19 total	73.00	16.94	115.26
		(9 m)	(± 3.38)	(± 1.95)	(± 15.24)
			67-78	14-22	87-141
	2	20 total	72.20	22.45	127.25
		(10 m)	(± 4.00)	(± 1.73)	(± 10.12)
			67-80	19-26	111-142

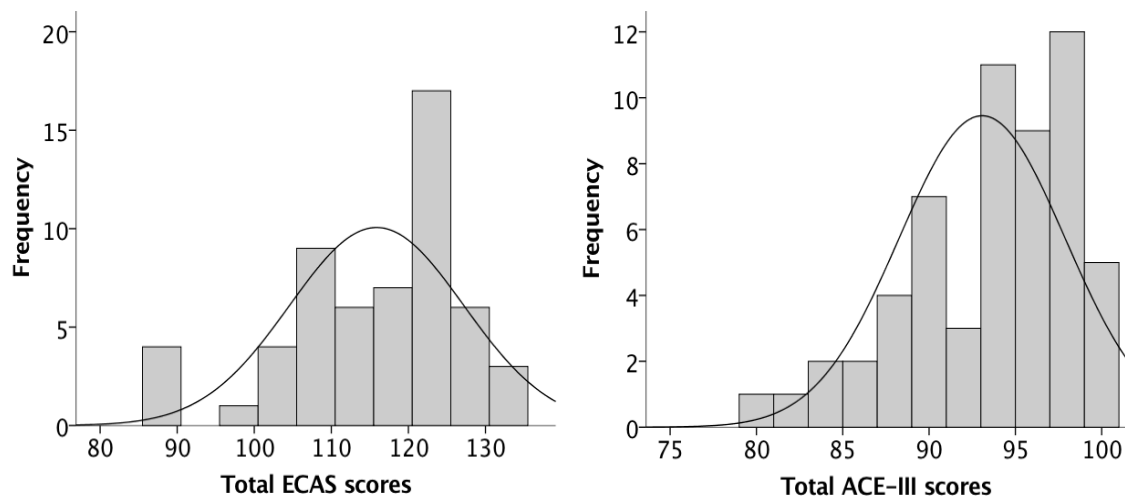
Education was divided between participants without a university degree (1) and participants with a university degree (2). m (presumably males). Results are presented Mean (Standard Deviation) Range.

Table 3: ECAS Age and Education adjusted cut-off scores to determine abnormality for ECAS Total Scores.

Age	Education	Mean (SD)	Range	Cut-off
≤65	1	119.650 (±8.628)	100-134	100
	2	123.381 (±7.221)	110-133	110
>65	1	117.000 (±8.062)	98-129	98
	2	120.895 (±6.315)	108-131	108

Education was divided between participants without a university degree (1) and participants with a university degree (2). Standard Deviation (SD)

Figure 1 Distribution of scores on the (left) ECAS and (right) ACE-III.



Edinburgh Cognitive and Behavioural ALS Screen (ECAS) mean 115.88 (±11.303), Addenbrooke's Cognitive Examination (ACE-III) mean 93.07 (±4.81).